

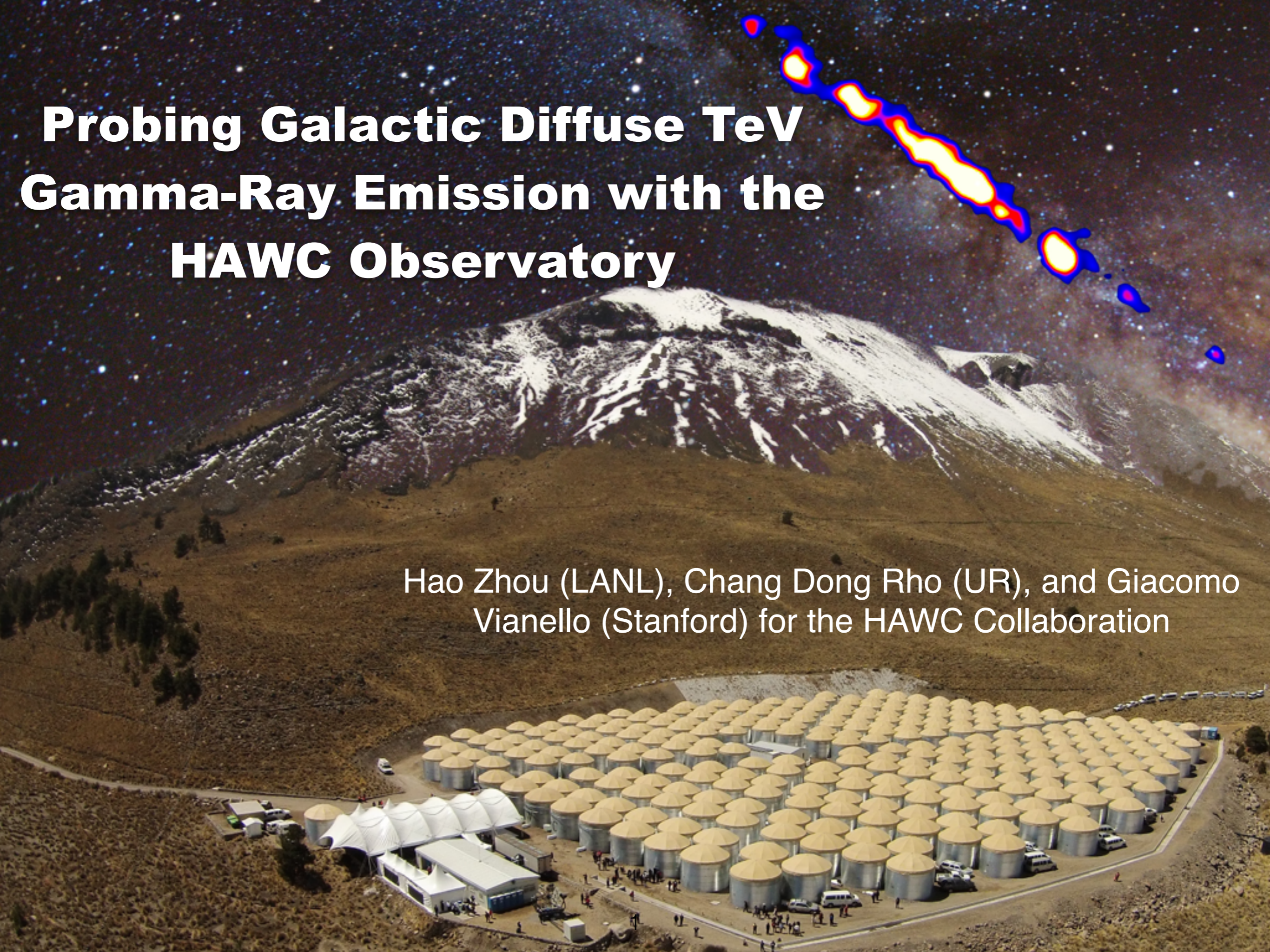
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Title:	Probing Galactic Diffuse TeV Gamma-Ray Emission with the HAWC Observatory
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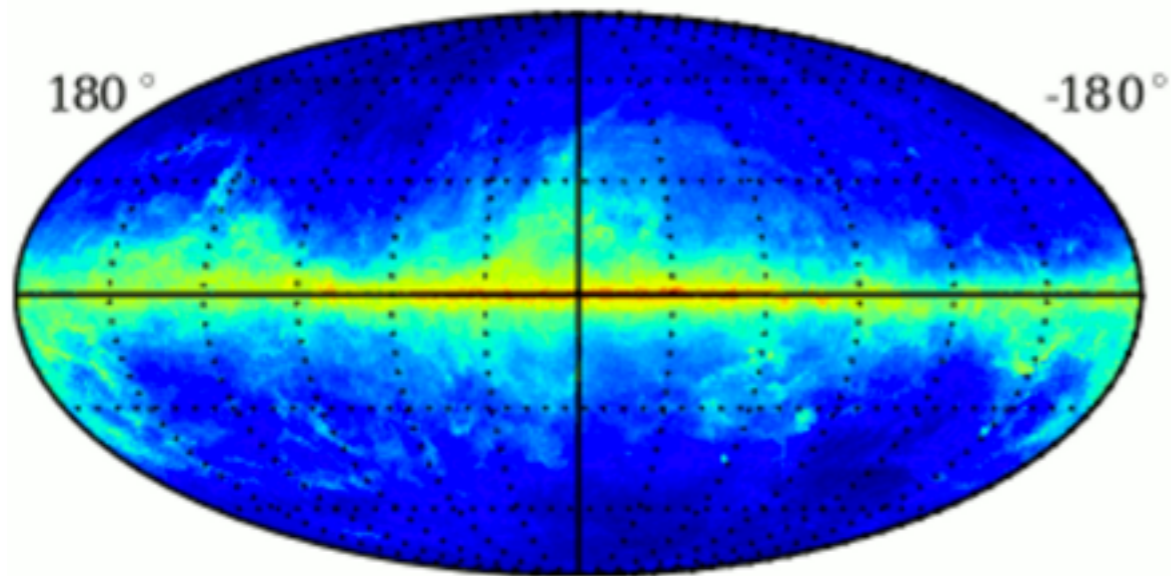


Probing Galactic Diffuse TeV Gamma-Ray Emission with the HAWC Observatory

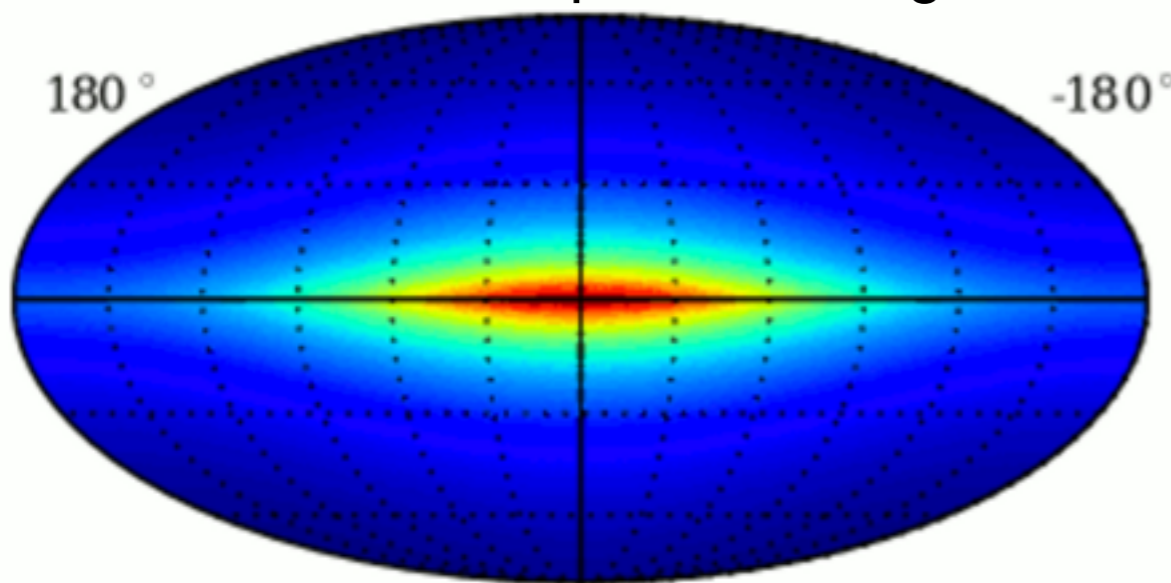
Hao Zhou (LANL), Chang Dong Rho (UR), and Giacomo Vianello (Stanford) for the HAWC Collaboration

Galactic Diffuse Emission

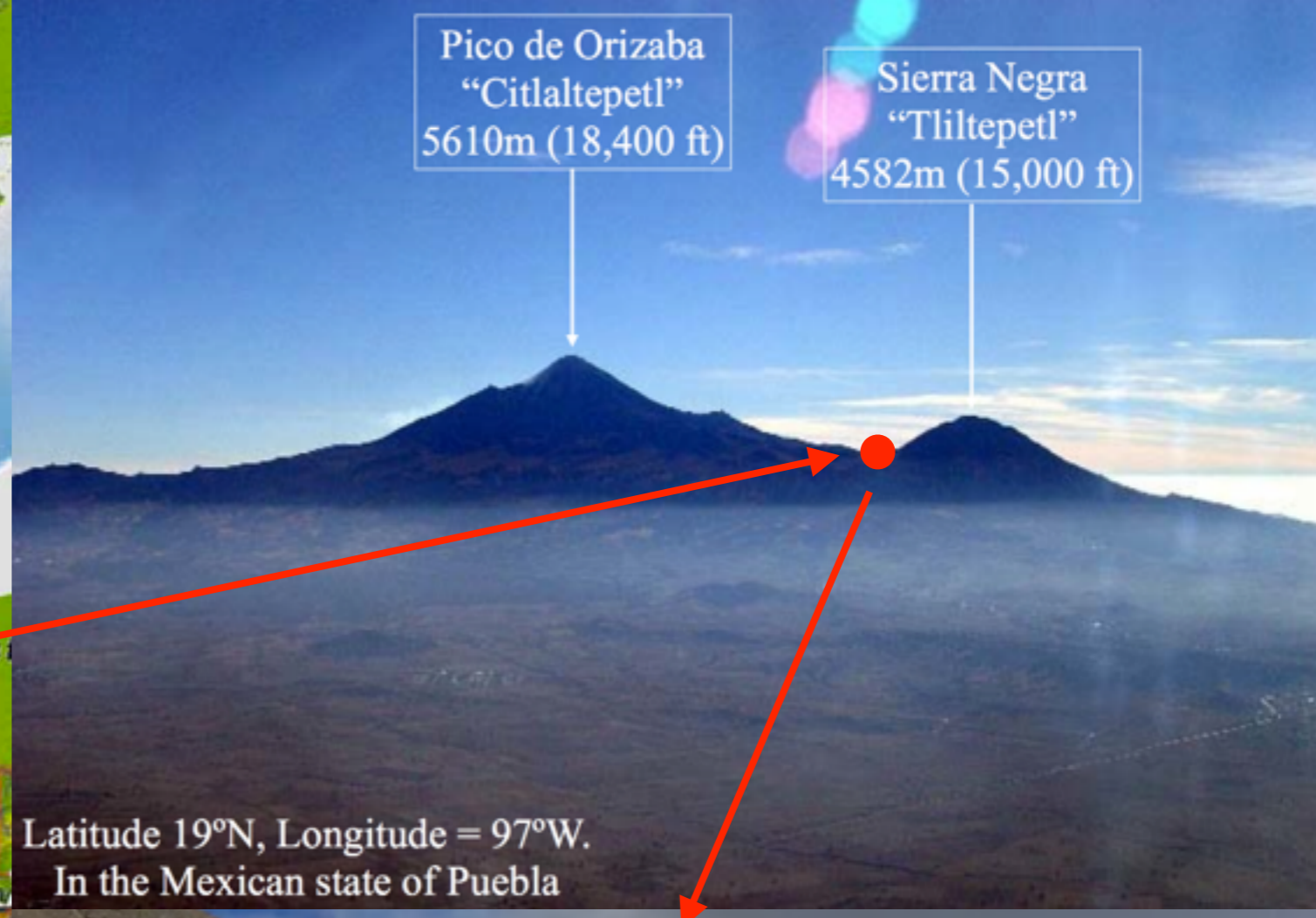
π^0 decay



Inverse Compton Scattering

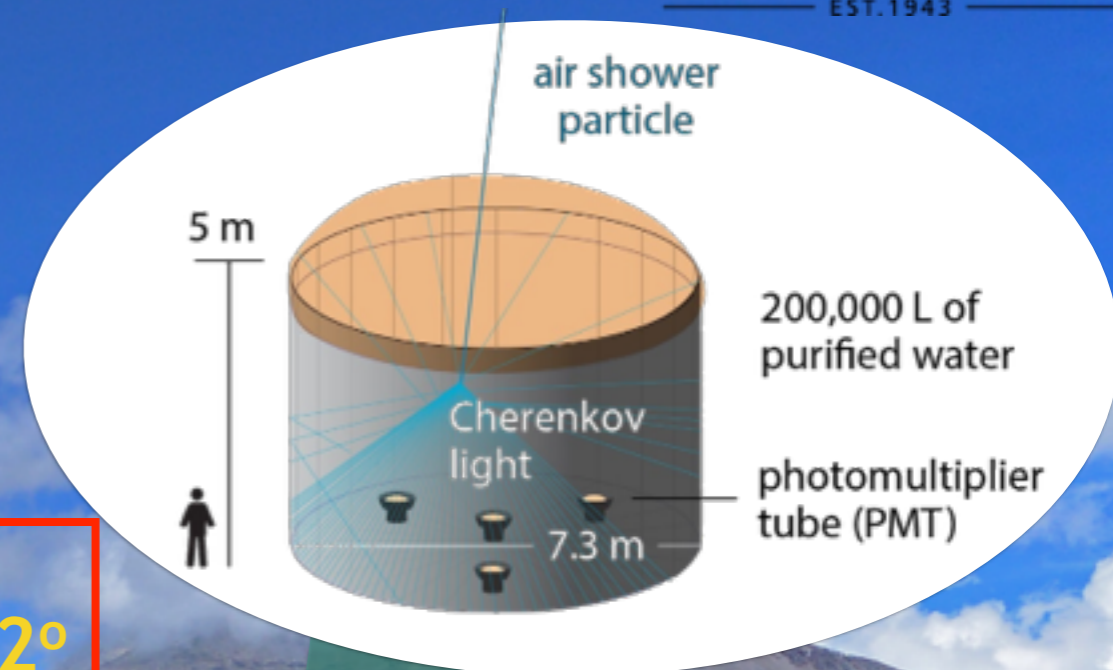


- Produced by cosmic rays interacting with the ISM and radiation fields
- At TeV energies:
 - π^0 decay: interaction between hadronic CRs and ISM
 - inverse Compton scattering: interaction between leptonic CRs and CMB
- By studying diffuse emission, we can learn about the acceleration and propagation of CRs in our Galaxy.



The HAWC Observatory

- Sub TeV to >100 TeV Sensitivity
- 300 Water Cherenkov Detectors
- $22,000 \text{ m}^2$ detector area
- High duty cycle: $>95\%$
- Wide field of view: $\sim 2 \text{ sr}$
- Angular Resolution (68% Cont.) $1.0\text{-}0.2^\circ$

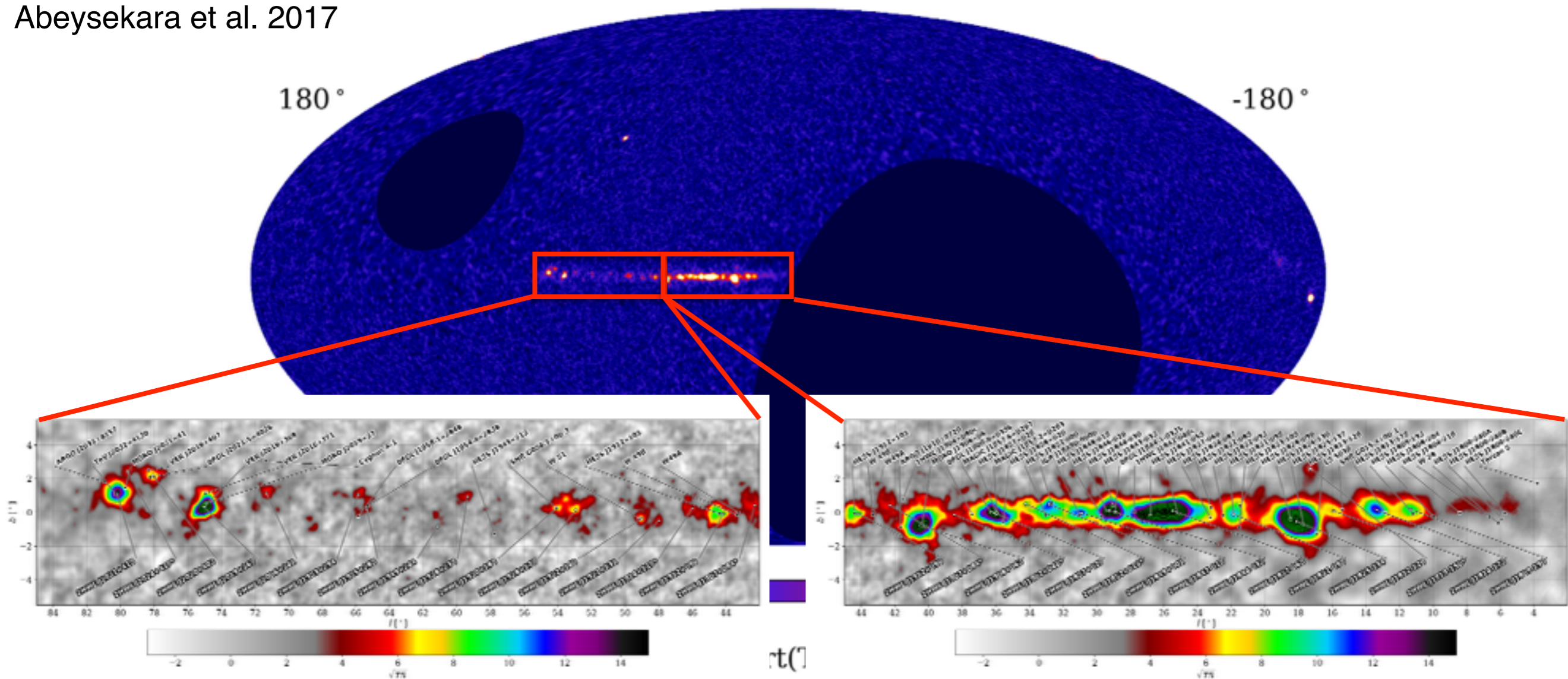


Excellent detector for extended sources

Full array inaugurated on March 20, 2015

17 Months of HAWC Data

2HWC Catalog
Abeysekara et al. 2017



Challenge on the diffuse emission studies:

at TeV energies, gamma-ray emission from sources (resolved and unresolved) dominates over the diffuse emission.

Flux Density Calculation

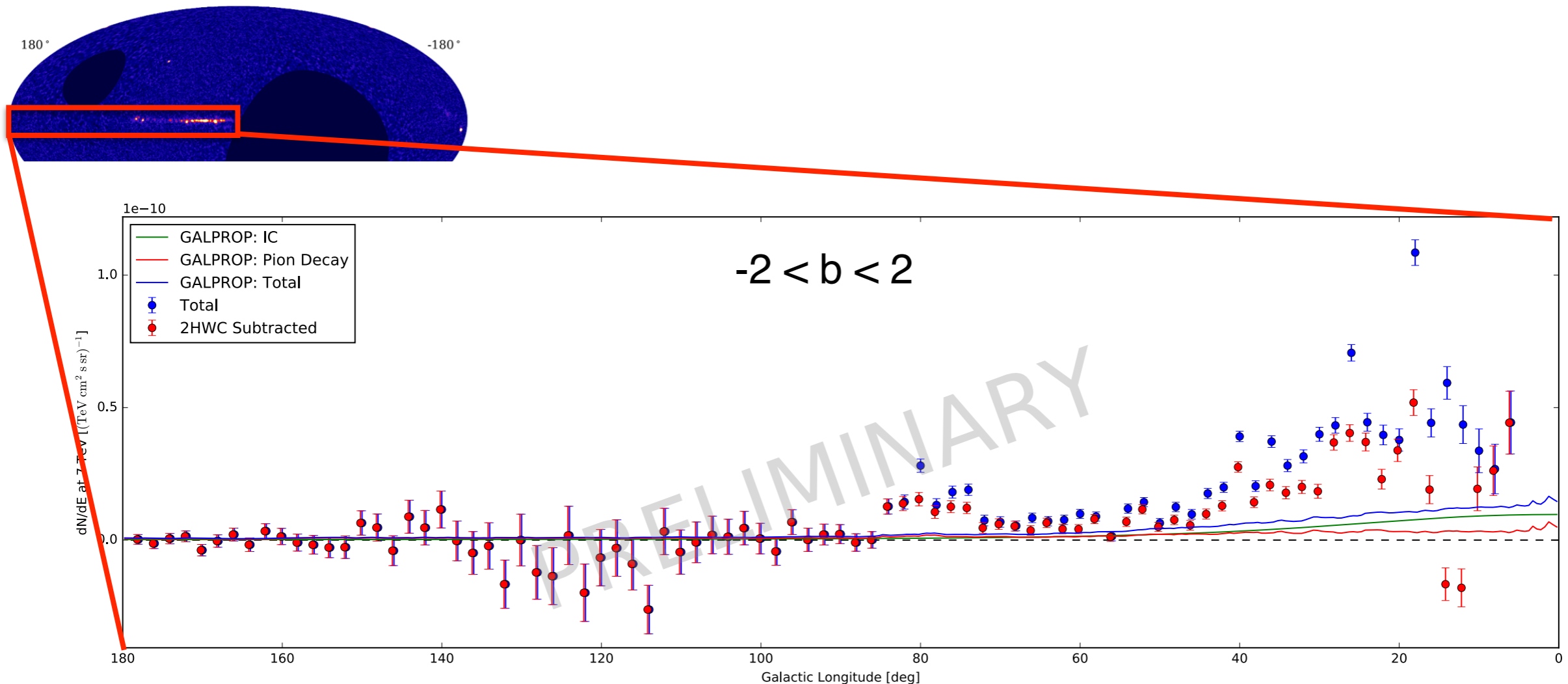
Flux density is calculated for each pixel in the map, by

1. subtracting emission due to 2HWC sources from the data excess counts
2. comparing source-subtracted data excess to the expected counts for a simulated source and calculating the flux density

$$S = \frac{\sum_{\mathcal{B}=1}^9 (E_{\mathcal{B}} \times GHW_{\mathcal{B}})}{\sum_{\mathcal{B}=1}^9 (M_{\mathcal{B}} \times GHW_{\mathcal{B}})} \times \frac{1.64 \times 10^{-13}}{a} (\text{TeV cm}^2 \text{ s})^{-1}$$

- \mathcal{B} - analysis bin, proxy of energy bins
- a - pixel area of the HAWC map
- $GHW_{\mathcal{B}}$ - weight based on S/N ratio in each \mathcal{B} bin
- $E_{\mathcal{B}}$ - excess count in data (raw data - background)
- $M_{\mathcal{B}}$ - expected count from detector response for a simulated source with
 - a flux normalization of $1.64 \times 10^{-13} (\text{TeV cm}^2 \text{ s})^{-1}$ at 7 TeV (Crab flux),
 - a spectral index of 2.75, chosen to match the cosmic-ray spectrum around 10 TeV.

Longitudinal Profile

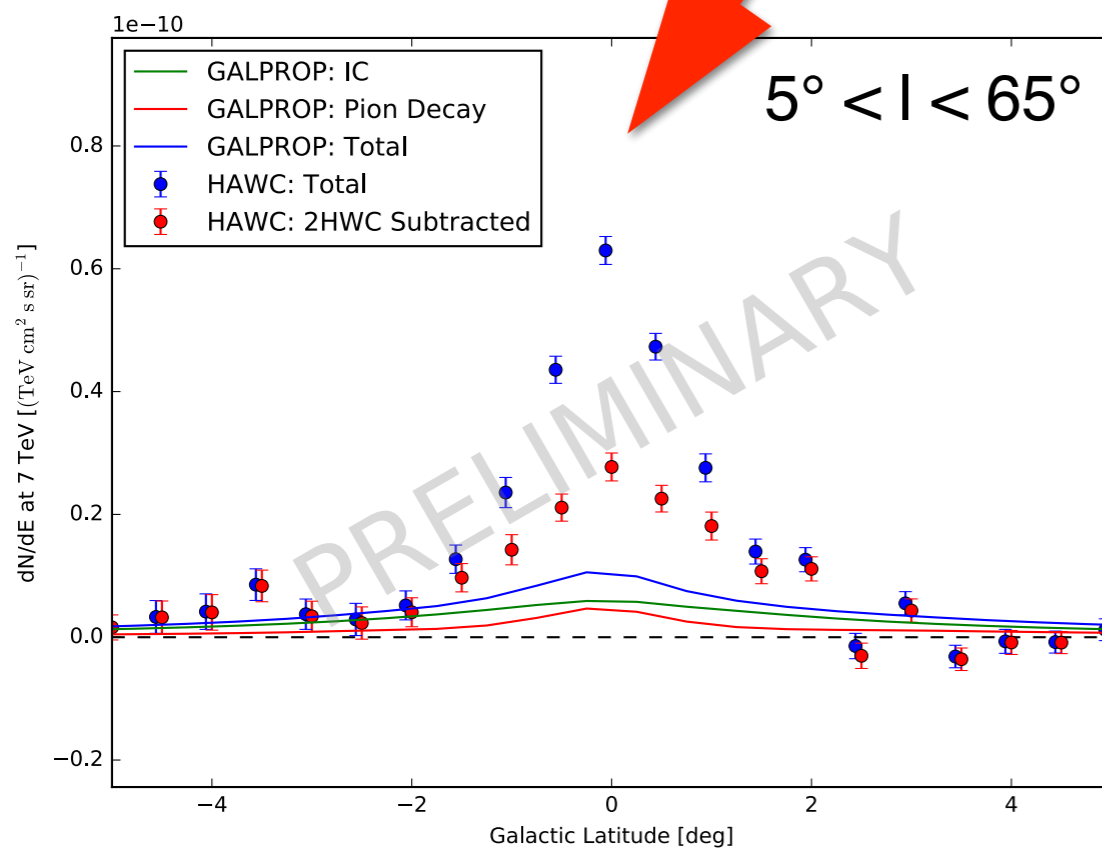
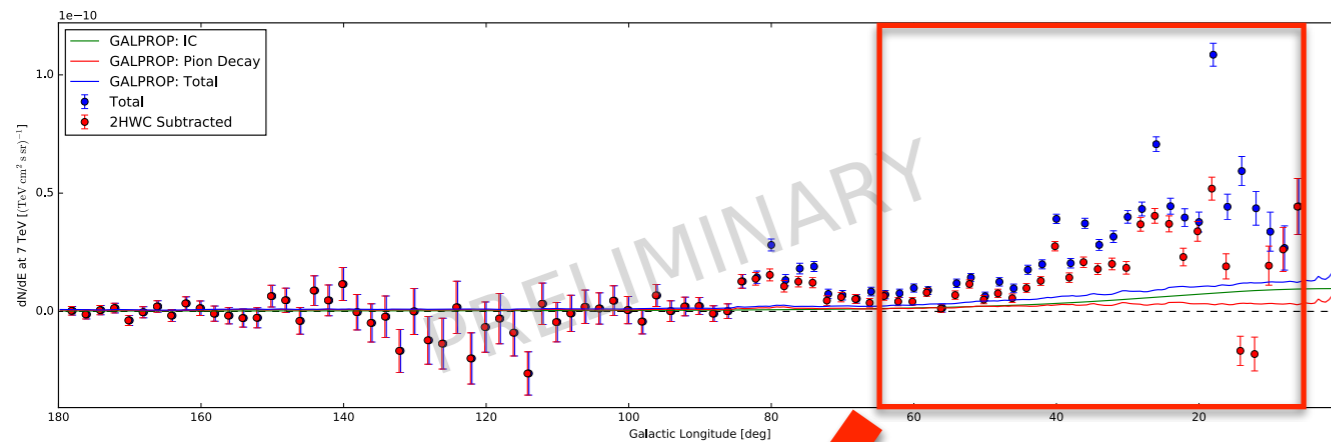


The resulting gamma-ray emission is a combination of

- extent of sources that 2HWC does not account for
- unresolved sources that are below the detection threshold
- Galactic diffuse emission

Latitudinal Profiles

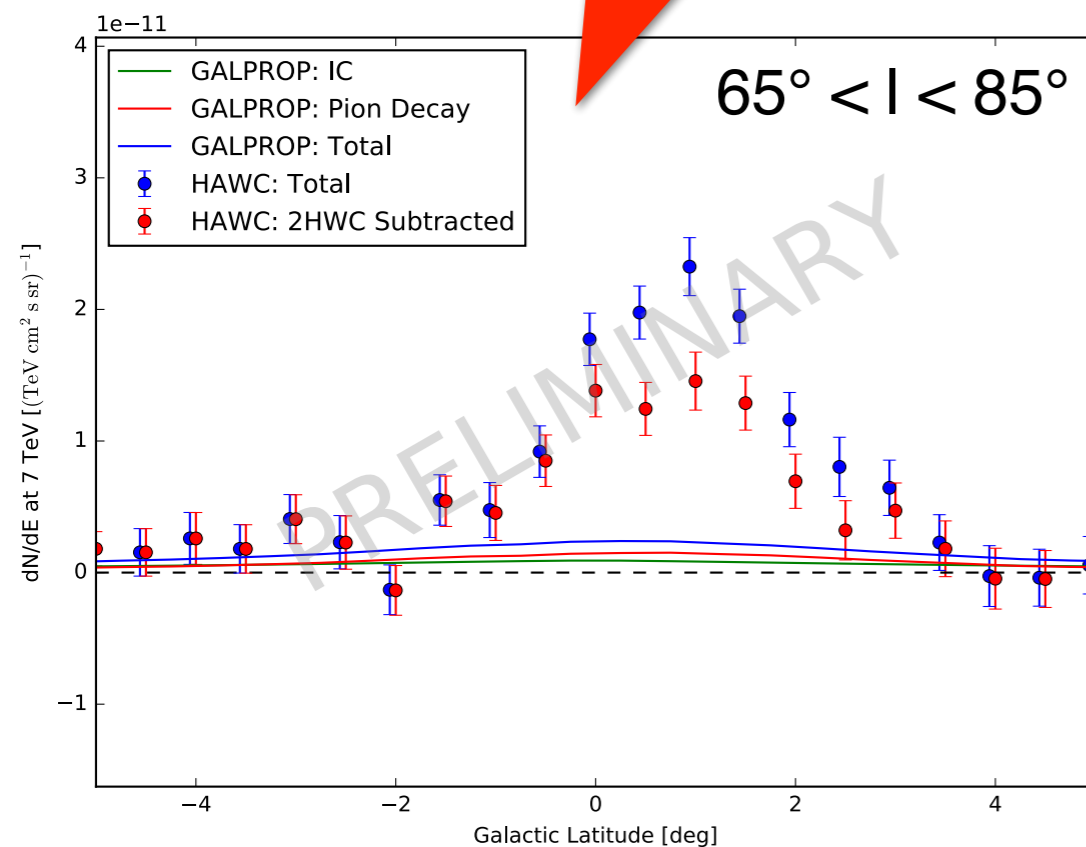
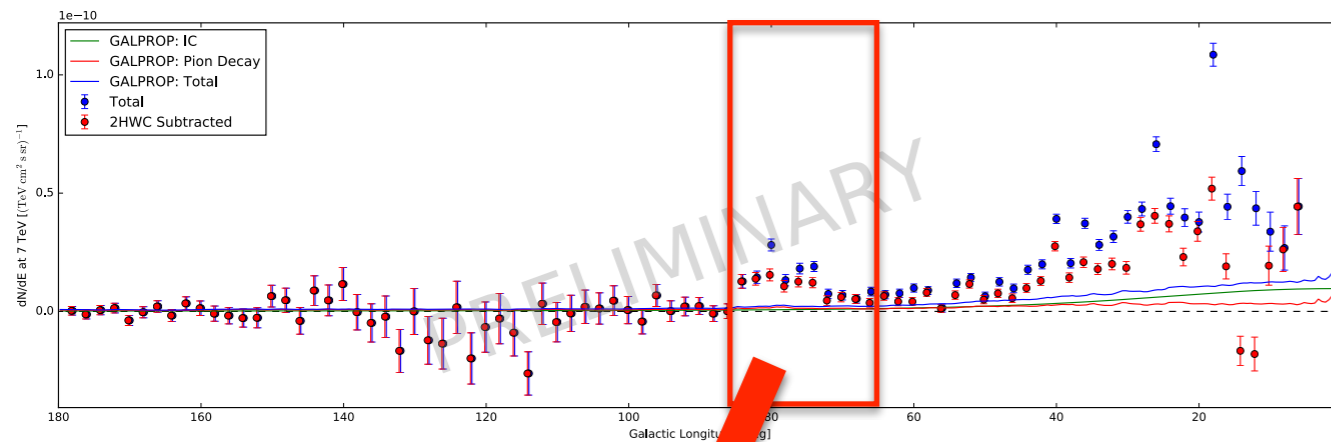
Inner Galaxy



- 24 sources identified in 2HWC
- Resolved sources account for about one third of the total emission
- Source-subtracted emission is 2-3 times of the emission predicted by GALPROP

Latitudinal Profiles

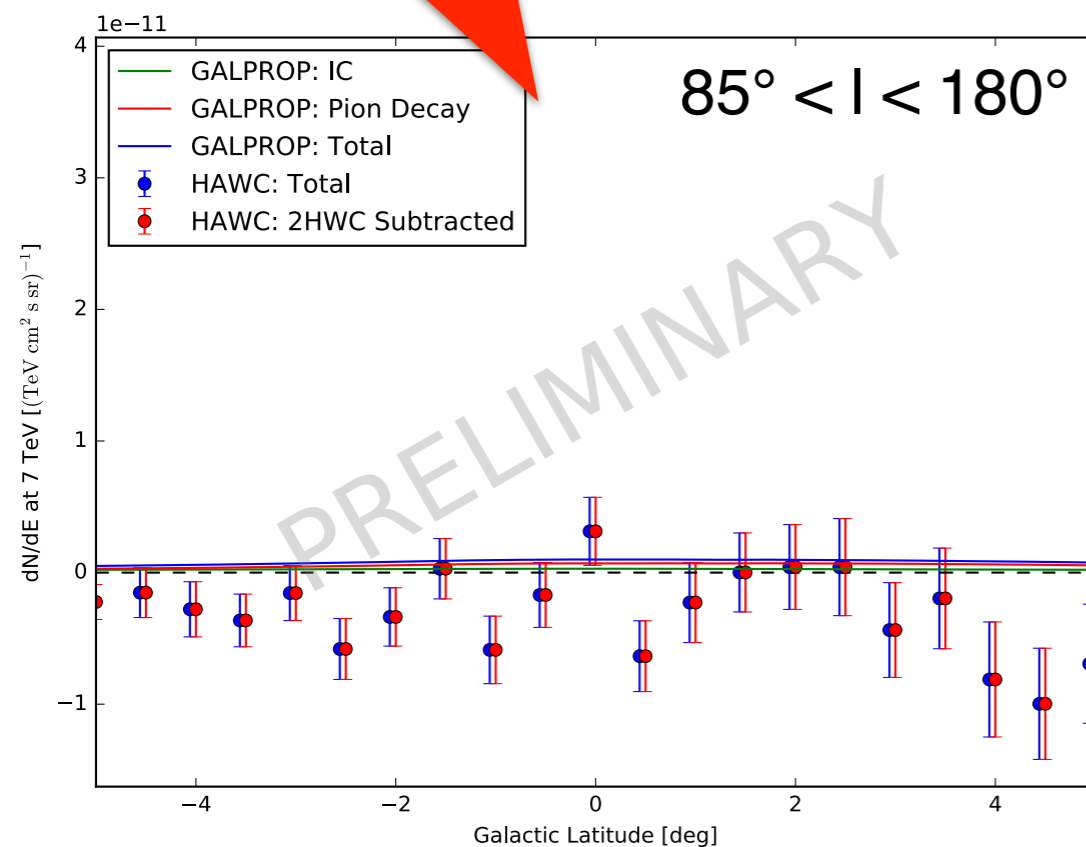
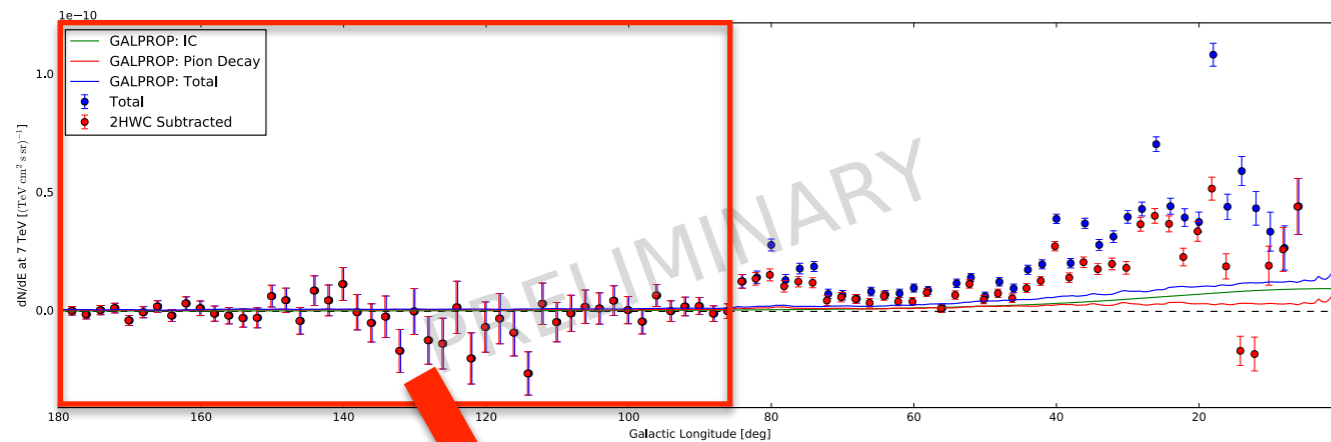
Cygnus region



- 7 sources identified in 2HWC
- Resolved sources account for about one fifth of the total emission
- Source-subtracted emission is an order of magnitude higher than the emission predicted by GALPROP

Latitudinal Profiles

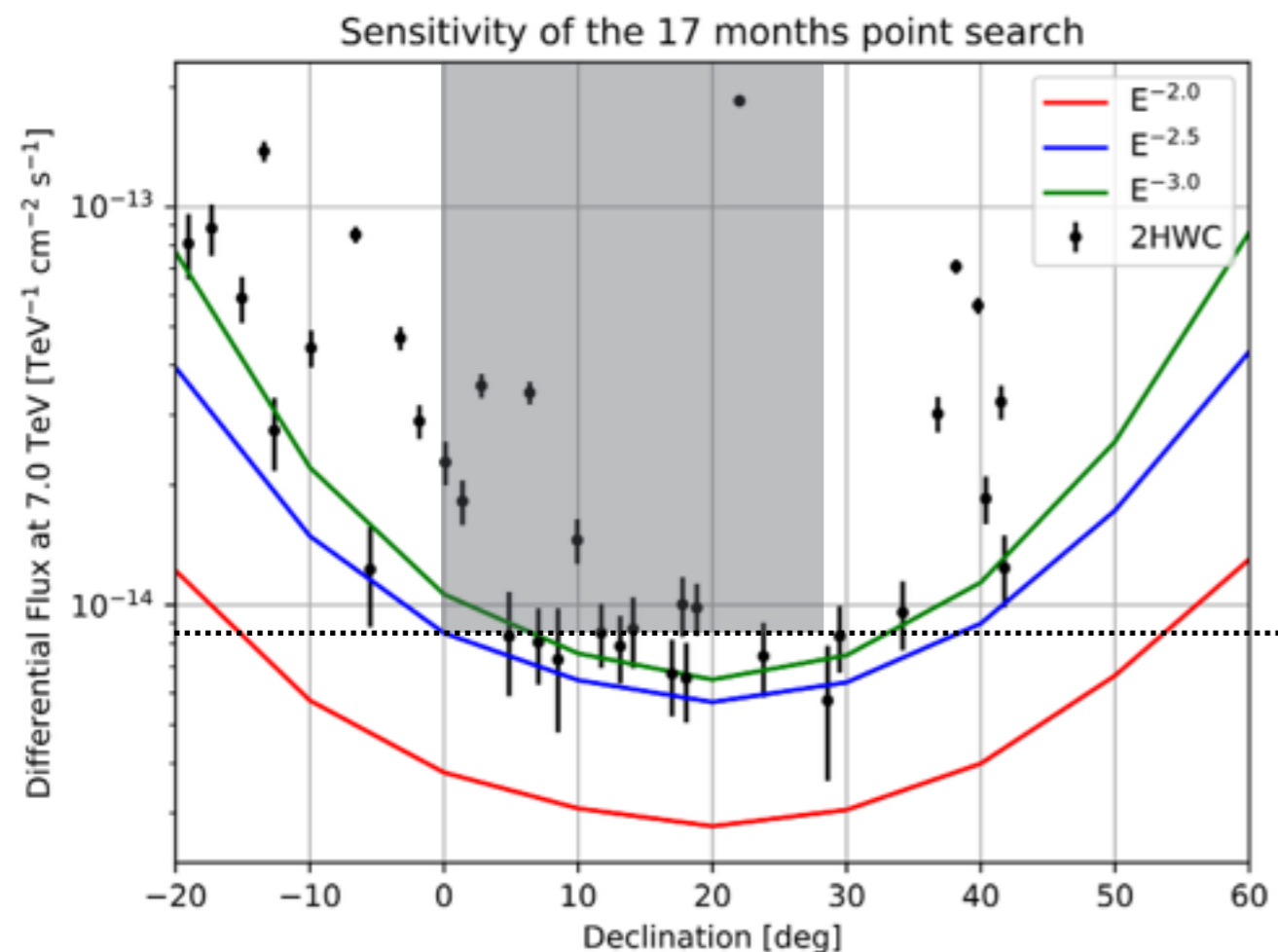
Outer Galaxy



- No source identified in 2HWC
- No significant gamma ray emission is found in this region

Unresolved Sources

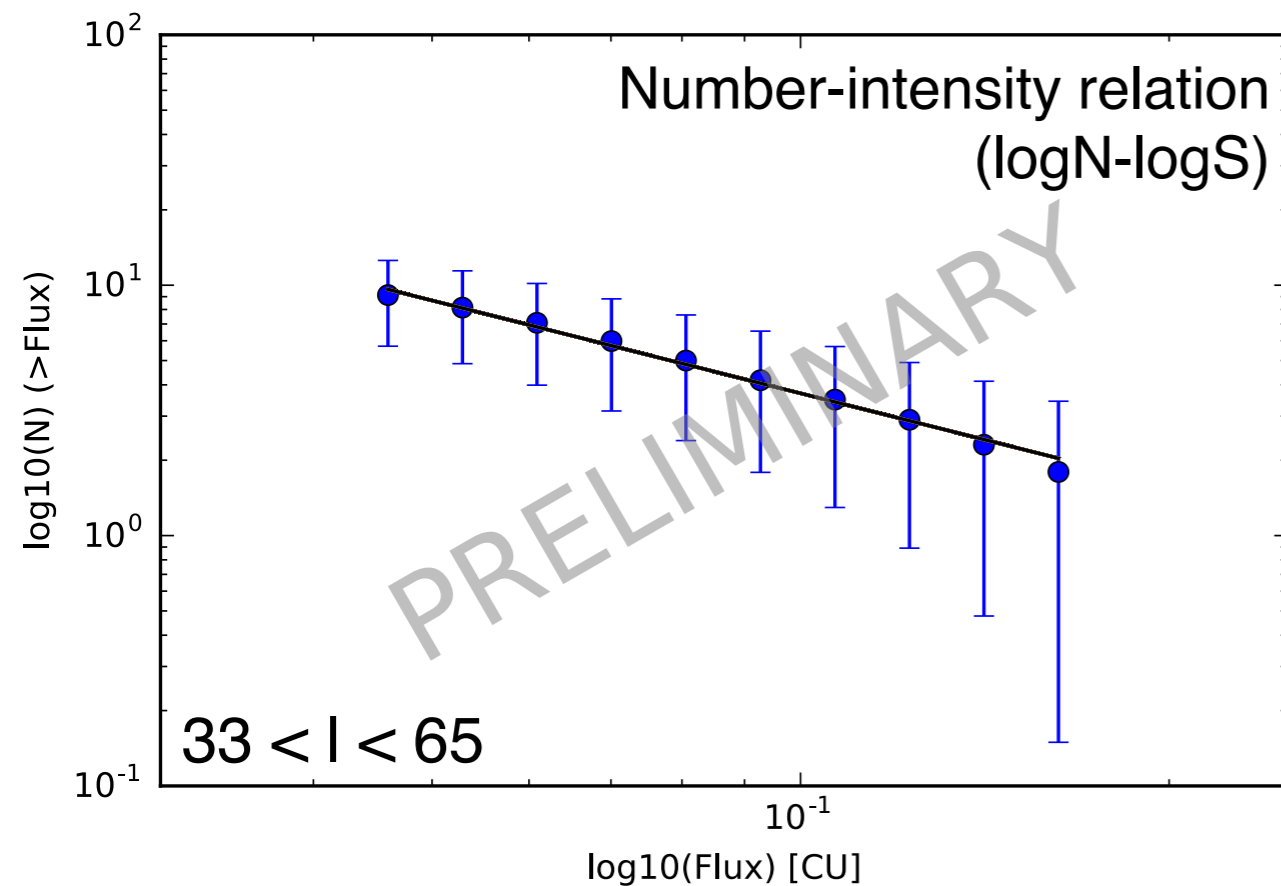
- In order to measure the true diffuse emission, an important question is how much emission the unresolved sources contribute.
- We use the method of number-intensity relation, i.e., $\log N$ - $\log S$ to estimate the source population that is below our detection threshold and the flux contribution.



- The region of $33 < \text{longitude} < 65$ is selected where HAWC sensitivity is rather flat.
- 14 2HWC sources in this region.

~5% CU

LogN-LogS Distribution



- **Obtained index: -1.2±0.4**
 - consistent with -1 expected from a uniform disk distribution
- **The uncertainty on index is large**
 - ongoing analysis: using all 2HWC sources to constrain the index (detector efficiency at different regions of the sky needs to be corrected)

- **X - flux normalization at 7 TeV in Crab unit**
- **Y - number of sources that are brighter than X**
- A toy MC is performed to account for statistical and systematical uncertainties on source flux.

Outlook

- **HAWC is sensitive to large scale Galactic diffuse emission**
- **The current measurements on the diffuse emission include:**
 - not perfect modeling of extended sources
 - unresolved sources that are below the detection threshold
 - true Galactic diffuse emission
- **Number-intensity relation method is used to examine the contribution from unresolved sources**
 - tested in a small region of the sky (large uncertainty on index)
 - ongoing analysis: using all 2HWC sources with more statistics (detector efficiency needs to be corrected)
- **Working on extended source modeling and multi-source fit (poster board #156 by C. Rho)**